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Diffusion of Automated Grid Transactions Through Energy Efficiency Codes

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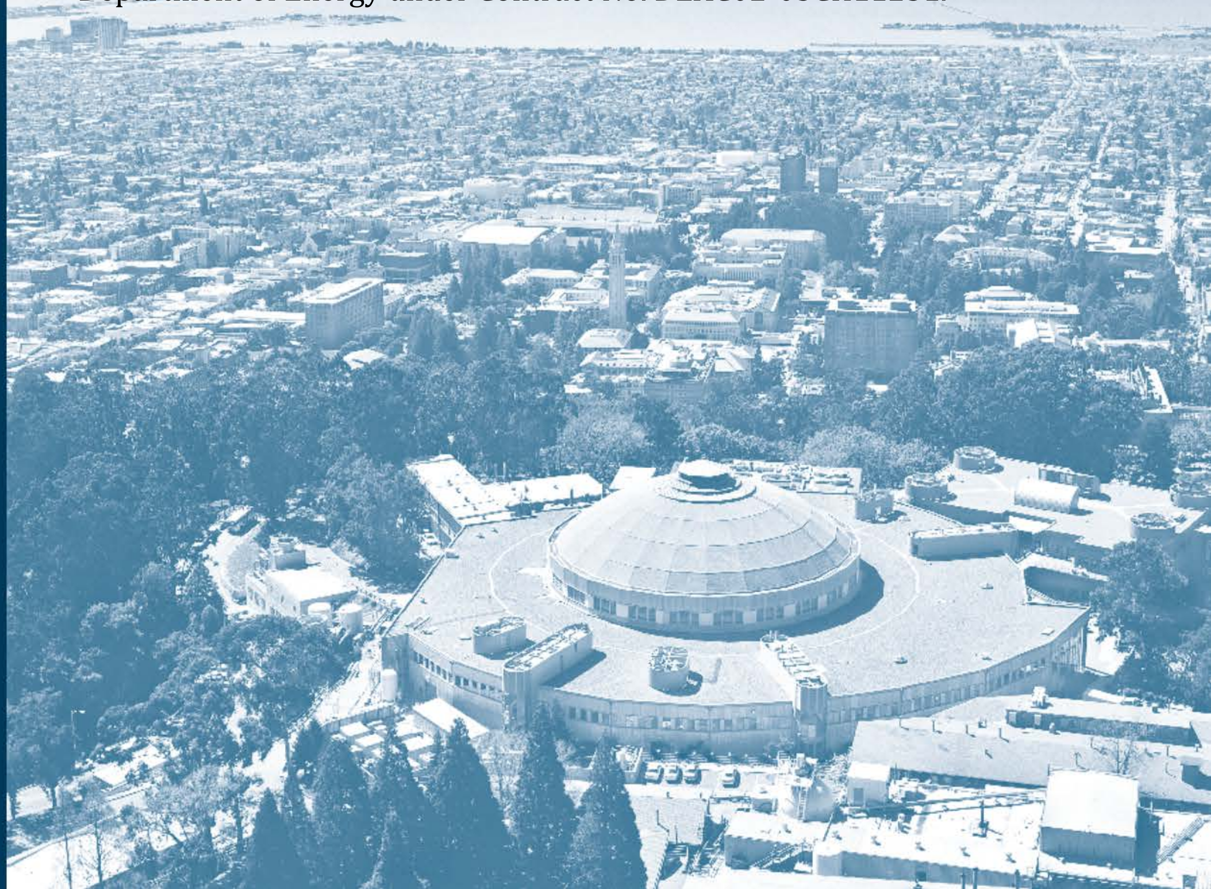

Diffusion of automated grid transactions through energy efficiency codes

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Abstract

Building codes have defined minimum requirements for the energy efficiency of building equipment and systems. There has been a growing interest in building codes that support standards for automation of demand responsiveness and grid transactions. These new codes to facilitate energy efficiency and demand response (DR) goals enable buildings to transact with the electric grid at various time scales. Energy efficiency and DR are at the top of the loading order in California and are important global strategies to lower carbon emissions and costs, and to optimize supply and demand. There is a strong need to educate building owners, vendors, and code officials on the intent of these new codes for electric grid transactions. The electric utilities must be engaged to take advantage of the DR automation capabilities in new buildings to advance sustainable and economically sound energy technologies and policies. This paper reviews recent work on this topic and the new requirements in California's mandatory 2013 Title 24 building energy efficiency standards that became effective on July 1, 2014. Title 24 has requirements for non-residential demand responsiveness and automation in lighting controls, plus heating and ventilation and air conditioning controls. It also requires the control system to be able to receive a standards-based demand response signal. The paper summarizes the history of how this feature was included in the code. The code language is intended to be general, as communications technology changes over every few years, and to provide guidance to enable architects, engineers, vendors, contractors, and building owners to have DR systems that can function with future technology. This paper provides an application of Open Automated Demand Response data and communication standards and how they can be used in Title 24 to lower technology costs and enable buildings and grid interoperability. We identify the significance of such building codes and discuss how the solution for adoption of DR automation in the United States can be applicable in Europe.

Introduction and background

In the United States (U.S.), national and state-level energy efficiency building codes for new construction and major retrofit scenarios have played an important role in providing energy, cost, and carbon savings. According to the U.S. Department of Energy (DOE), by 2040 energy efficiency building codes are projected to save U.S. businesses and electricity consumers about 44 quads of primary energy. This has resulted in about €200 billion ($230 billion USD) in cost savings, and reduced about 4 billion tons of carbon emissions (DOE 2014). Since 1977, the California Energy Commission's (CEC) mandatory Building Energy Efficiency Standards, also known as Title 24 building codes (henceforth, referred to as "Title 24") have saved California's energy customers over €65 billion ($75 billion USD) in reduced electricity bills (CEC 2012a). A deficiency of these building codes is that they only focus on energy efficiency improvements and DR readiness is overlooked.

The electric load shape of building loads drives the peak demand of the electric grid. Since the aging electric distribution network across the U.S. and California is fragile, system over-loads caused by excessive demand from buildings can create problems for the network. Blackouts can seriously disrupt consumer services and business, at the cost of billions of dollars. Since the California electricity crisis of 2000–2001, California has placed more and more emphasis on demand reductions.

Attention is growing on the need to develop peak electric demand reduction capability in buildings and lower the costs to enable DR automation. California's loading order requires the electric utilities to develop energy efficiency programs. Next in the loading order are DR programs to "reduce or curtail loads during times of high demand and emergencies" (CEC 2005). The growing need to reduce peak loads reliably, and to identify flexibility in building loads, has lead to the mandatory DR automation requirements in Title 24. California has placed more emphasis on demand reduction through building codes. The DR-related requirement first appeared in the 2008 Title 24 building codes. The 2008 Title 24 building codes were expected to deliver demand savings of 132 megawatts (MW) each year (CEC 2009).

Receiving the DR signals from a service provider, and automated response from controls with no human intervention, is the key requirement for automated demand response (AutoDR)-ready controls, which greatly increase customer participation. The scope of the DR requirement in 2008 Title 24 building codes was limited to lighting controls, and there was no clarity in code language requiring AutoDR in lighting controls upon receipt of a DR signal. This lack of clarity in the code language and exclusion of the acceptance tests for AutoDR-ready lighting controls have hindered the potential increase in the expected adoption rates.

The newest 2013 Title 24, which went into effect from July 1, 2014, requires automated demand response for lighting; heating, ventilation, and air conditioning (HVAC); and electronic messaging centers (EMC) (CEC 2012b), with requirements for acceptance tests in varying degree of detail. Fully automated demand response does not involve human intervention, but is initiated at a building through the receipt of an external communications signal. The building manager can execute manual DR by dimming the lights or changing the temperature set points. With AutoDR, the receipt of an external signal initiates pre-programed DR strategies in a building (Piette et al. 2009). The implementation of 2013 Title 24 is expected to reduce the annual electricity consumption by about 613 gigawatt-hours (GWh), and peak demand by 195 MW (CEC 2012b). Local government agencies can enforce Title 24 for new construction and retrofit conditions set forth by the California Energy Commission.

This paper summarizes the results of recent efforts to improve understanding of the complex concepts and terms defined in the new Title 24 language regarding DR automation. The new 2013 Title 24 code concepts have the potential for AutoDR diffusion[1] and lower DR technology costs, and encourage more cost-effective and greater levels of automated grid transactions in buildings.

1. Here the term "diffusion," which is adapted from "Simulating Energy Technology Innovation" by Ernest J. Moniz, indicates accelerated uptake of code adoption and use of AutoDR technologies.

STUDY OBJECTIVES

The study objectives, which focus on AutoDR requirements in 2013 Title 24 for new construction, are to:

1. Work with key energy efficiency and DR stakeholders to identify and document new AutoDR compliance requirements and gaps for code diffusion.
2. Develop and propose technical recommendations and guidance language for the "standards-based messaging protocol" as defined in Title 24.
3. Identify mechanisms for the stakeholders to understand AutoDR compliance for acceptance testing and propose diffusion strategies.
4. Propose recommendations for AutoDR diffusion, which considers technology costs, obsolescence, and interoperability.

BACKGROUND

Energy codes historically have defined minimum requirements for the energy efficiency of building equipment and systems. There is growing interest in energy codes to support requirements for demand responsiveness and grid integration (Energy Performance Services. No date). The recent requirements in California's 2013 Title 24 make the statewide DR and automation goals mandatory for non-residential buildings. Such measures are essential to enable buildings and their end-use systems to participate in AutoDR programs. The "enablement" refers to the readiness of the controls to have native AutoDR capability that customers can use to participate in the DR program(s). Title 24 requires the use of a "standards-based messaging protocol" for DR signals, which are sent by the DR service provider (e.g., utility, independent system operator, aggregator) to the customer.

Since 1977, California's Title 24 energy standards were developed to improve the energy efficiency of residential and non-residential buildings. The first code was enacted by the California legislature in 1978. The philosophy of building codes is that reduction in energy consumption is a benefit to all because consumers save money and have a more secure, healthy economy; the environment is less impacted; and our electrical system becomes more stable.

ORGANIZATION

The paper is organized to provide a review of 2013 Title 24 AutoDR requirements for HVAC, lighting controls, and sign lighting, and to identify AutoDR compliance and diffusion gaps. Based on the identified gaps and key stakeholder workshops and surveys, we recommend strategies to improve AutoDR compliance and encourage code diffusion. We wrap up by outlining the key discussion topics, conclusions, and future research directions.

California Title 24 codes and demand response automation

This section provides key concepts and links between energy efficiency and DR automation. We describe terms, as well as the technology and communication framework that enables interoperability and lower adoption costs. Also we describe the requirements for and benefits of AutoDR in 2013 Title 24, code triggers, and acceptance testing.

The 2013 Title 24 requires AutoDR capabilities in residential and non-residential HVAC control systems, including occupant-controlled smart thermostats (OCST) and lighting controls, including sign lighting (called *electronic message centers* or *EMCs*), that automatically receive and respond to DR signals. The original intent to use DR signals and automation in Title 24 was based on three objectives:

1. Provide guidance to architects, engineers, vendors, and contractors as they specify, design, and build systems in the future (i.e., so they understand the intent of the AutoDR code requirements).
2. Prevent AutoDR code language that could become irrelevant or counterproductive due to changes in the AutoDR signal for a standards-based messaging protocol that may arise over the next several years.
3. Enable AutoDR control measures in buildings to multiple retail and wholesale DR markets signals that have different response timescales (i.e., day-ahead or day-of).

The 2013 Title 24 requires DR automation to HVAC, indoor lighting, and sign lighting. Outdoor signs, non- residential and high-rise residential buildings, and newly constructed hotels and motels – as well as major retrofit projects – must comply with AutoDR-related requirements, as summarized in Table 1.

ENERGY EFFICIENCY, DEMAND RESPONSE, AND AUTOMATION: CONCEPTS AND TERMS

The 2013 Title 24 prescribes mandatory requirements for energy efficiency (EE), manual DR, and AutoDR. The significant differences between EE, DR, and AutoDR are not clearly defined in the 2013 Title 24, and the public has often misunderstood them. The International Energy Agency (IEA) defines energy efficiency as a way of delivering "more services for the same energy input, or the same services for less energy input" (IEA. No date). In the 2013 Title 24, DR is defined as, "short-term changes in electricity usage by end-use customers from their normal consumption patterns. It may be in response to (a) changes in the price of electricity; or (b) participation in programs or services designed to modify electricity in response to wholesale market prices or when system reliability is jeopardized" (CEC 2013a). AutoDR takes the concept one step further: while DR allows customers to control and manage equipment and systems by receiving and manually responding to the DR service provider's request, AutoDR connects customers' equipment and systems to the utility's DR management systems and enables a fully automated response, with no human intervention.

In the context of AutoDR, which is the focus of this study, the following terms and definitions from Title 24 and its joint appendices (JA) are important. These definitions summarize DR messages, protocols, and controls needed for automated response (CEC 2013a and CEC 2013b).

1. ***Demand Response Signal*** is a signal sent by the local utility, Independent System Operator (ISO), or designated curtailment service provider or aggregator to a customer, indicating a price or a request to modify electricity consumption for a limited time period. The DR signal attributes and requirements shall be specified within the messaging protocol utilized by the utility or other entity selected by the occupant.
2. ***Demand Responsive Control*** is a kind of control that can receive and automatically respond to a DR signal.
3. ***Demand Response Period*** refers to the period of time during which electricity loads are modified in response to a DR signal.[2]
4. ***Price Signal*** refers to a utility or another entity providing pricing information to the occupant and initiating demand responsive control for the DR period utilizing a DR signal.
5. ***Standards Based Messaging Protocols*** refers to the information model used to represent messages sent to the OCST. There is no mandated specification, but direction is provided as "standards based messaging protocols (including but not limited to Smart Energy Profile (SEP), OpenADR or others defined in the Smart Grid Interoperability Panel (SGIP) Catalog of Standards (CoS)." This direction applies to the OCSTs and not to other HVAC systems and lighting systems.

DEMAND RESPONSE AND AUTOMATION

The benefits of interoperability in decoupled technology developments and markets for both electricity grid and building systems have been well studied (Ghatikar and Koch 2012 and Ghatikar et al. 2013). Facilitating the adoption of these fundamental concepts in Title 24 is critical to ensure plug-and-play integration of both grid and building systems. The AutoDR challenge that's unique from energy efficiency and manual DR is **how to ensure original building equipment is AutoDR compliant when an unknown external AutoDR provider (e.g., utility) sends the DR signals to a customer.**

Standards-based messaging protocols for DR are necessary to ensure that a customer's installed AutoDR equipment is interoperable, can be enabled for plug-and-play operation, and are ready to participate in AutoDR programs. AutoDR interoperability from Smart Grid data standards is well studied (Ghatikar et al. 2014a). We describe the messaging protocols and DR signals from 2013 Title 24 in the context of the widely used Open Systems Interconnection Reference Model (OSI model). The seven-layer OSI model, as shown in Figure 1, is an important framework for well-defined communication interfaces to any networked system. This communication architecture can be collapsed into three main domains: (1) physical, (2) network/transport, and (3) application. Of these, the physical domain is the most capital intensive to develop and deploy. The network/transport domain is usually based on the Internet Protocol (IP). The application domain is where the most innovation happens and where the data constructs for multiple AutoDR programs and cyber-security are defined. There is a direct link between these communication interfaces for: (1) messaging protocols at the physical domain, and (2) DR signals at the network/transport and application domains.

2. The technical specifications for OCST mention that the event response, unless overridden by the occupant or modified by an energy management control system or service, can be triggered by price signals or demand response signals (CEC 2013b).

Table 1. Occupancy types and AutoDR-related requirements.

Occupancy Type	AutoDR-related Requirements	
	Demand Responsive Lighting Controls +	Centralized Energy Management Control System for HVAC systems and EMCs
Non-residential, High-Rise Res., and Hotels/Motels	X	X
Signs	X	X

+ Applicable to indoor lighting controls and Electronic Message Center (EMC) controls.

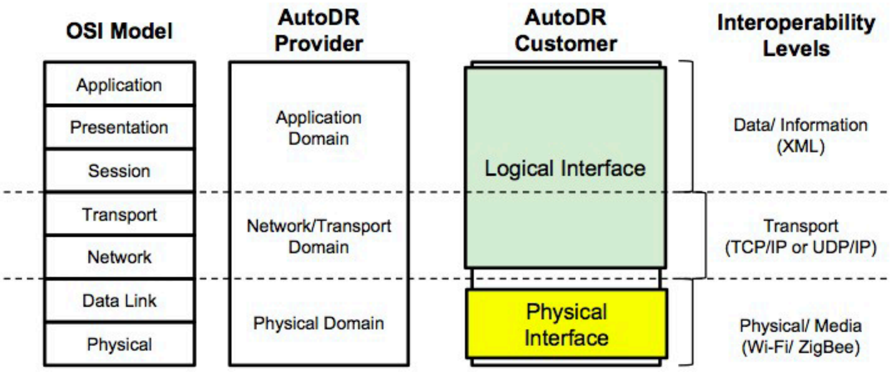

Figure 1. Interoperability levels for DR signals and messaging protocol.

The 2013 Title 24 describes these communications as *physical interface* (protocols) and *logical interface* (signals). In 2013 Title 24, the *physical interface* includes "a one- or two-way communications interface as selected and specified by the occupant's utility, information update service or DR service provider and enabled by either onboard communications devices or a communications module in the case of an expansion or communication port." One-way communication refers to a system where there is no acknowledgement between the sender and the receiver of DR signals. This could be an issue, as AutoDR service providers require the confirmati n of the receipt of the DR signal. The *logical interface* "consists of the information model used to represent messages" sent to demand responsive controls. For *logical interfaces* to be communicated over any *physical interfaces* and not become obsolete requires standards-based messages and a mechanism to test and certify its compliance. This enables support by any manufacturer or market-based mechanism for physical interfaces that a customer might choose. While there is no mandated standard for the logical interface, Title 24 provides guidance language for the term "standards based messaging protocols."

To ensure that the *logical interface* provides demand responsive control and plug-and-play capability for AutoDR program participation, use of nationally recognized and industry-supported standards are key. The key advantage of mandatory requirements for the use of national standards for DR and price signals is facilitation of interoperability and cyber-security for DR signals between the DR service provider's distribution systems and the customers' control systems (Ghatikar 2014a). The DR standards must be "open," meaning that the specifications or standards are publicly available for developers to use to build interoperable systems. Figure 2, from an earlier study, shows key advantages associated with such systems. Also, for effectiveness, the costs of enabling AutoDR can be nominal, especially when added and certified during new construction (Gonzalez et al. 2014; Piette et al. 2014).

Interoperability challenges arise because; service providers need to adopt one or a few standards for DR signaling systems (certified AutoDR servers), knowing well that the building loads or systems can respond to the signals (certified AutoDR clients). The vendors also benefit, as they can develop new products with same standard software, knowing well that these building loads or systems can easily interoperate with AutoDR program signals.

Considering these key principles, there is a potential to improve the language of 2013 Title 24 AutoDR definitions of terms, guidelines, and acceptance testing criteria for the controls and equipment subject to Title 24 compliance acceptance testing. Such improvements will enable the development of interoperable demand responsive controls and equipment that can respond to external DR signals and eventually lead to DR-ready controls and low-cost automation through diffusion.

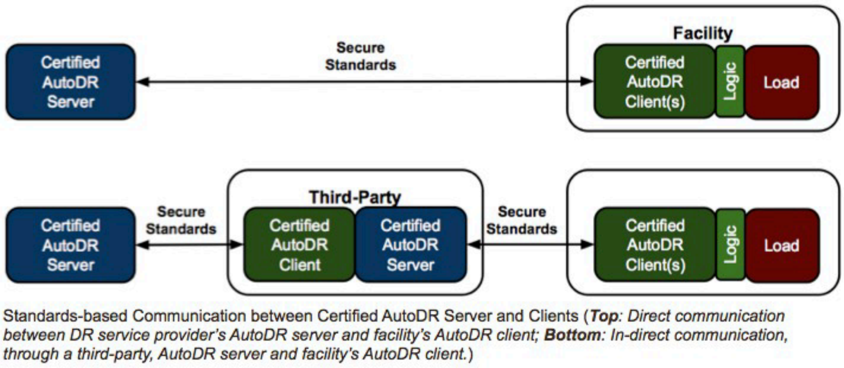

Figure 2. Standards-based communication between the AutoDR Server and clients (Gonzalez et al. 2014).

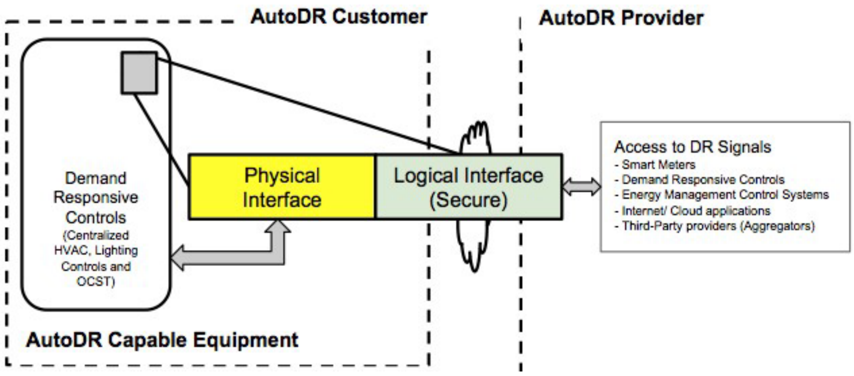

Figure 3. Mapping physical and logical interfaces for demand response signals.

AUTOMATED DEMAND RESPONSE REQUIREMENTS, TRIGGERS, AND ACCEPTANCE TESTING

While the principles for DR and automation at both physical and logical interfaces enable interoperability and address technology obsoleteness, the system architectures describe implementation mechanisms for those principles. Here, we describe the technology architectures and signaling requirements for different end uses and their systems for AutoDR, as specified in the 2013 Title 24 language.

Figure 3 maps the logical and physical interfaces from 2013 Title 24 demand-responsive controls for centralized HVAC systems, occupant-controlled smart thermostats (OCST), and lighting control systems. This generic architecture can also be used as a reference to a centralized Energy Management and Control System (EMCS), as it shows a common and secure logical interface between the service provider and customer. Since each customer selects a communication system of his or her choice, such logical interfaces must be agnostic to physical interfaces. As long as the logical interface is based on open standards, AutoDR equipment can be tested and certified for compliance before its installation. For the final AutoDR compliance and acceptance tests, a code-check official must inspect the certification of the logical interface, test load-control strategies, and verify equipment response to a DR signal. Such minimum provisions give a clear message to all stakeholders and enable mass production of AutoDR-ready equipment without affecting customer and equipment manufacturer technology selection.

While Title 24 documents do not define the aforementioned level of technical detail for AutoDR compliance, the end uses that are subjected to the requirements include both new construction and major retrofits.

A code triggering retrofit for indoor lighting controls is very specific to projects where at least 10 percent of luminaires in a given space are altered. The previous threshold from the 2008 Title 24 was 50 percent, or where at least 40 luminaires were modifications-in-place. AutoDR requirements for lighting controls are summarized in previous studies (Lutron 2014).

Table 2 summarizes 2013 Title 24 AutoDR-related requirements that are mandatory for the following categories: (1) End-use system, (2) AutoDR triggering conditions, (3) system response requirements to a DR signal, (4) equipment needed for compliance, and (5) acceptance test requirements.

For OCSTs, the CEC oversees the self-certification process with manufacturers with no other mandated specifications for the standards-based messaging protocol except that "the communications capabilities shall enable demand responsive control through receipt of DR signals based on communications standards" (CEC 2013b). The lists of self-certified products can be found on CEC's website.[3]

An example and industry-supported standard for DR and price communication for the interoperability of the *logical in-*

3. Refer CEC website: http://www.energy.ca.gov/title24/equipment_cert/ocst/.

Table 2. Summary of AutoDR requirements and acceptance testing.

End Use System	**AutoDR Triggering Conditions**	**System Response Requirements to a DR Signal**	**Equipment Needed for Compliance**	**Acceptance Test Requirements** **1. Construction Inspection** **2. Functional Testing**
Lighting Controls	• Building area ≥ 10,000 square feet • Habitable spaces where lighting power density is > 0.5 watts/ square foot	• Reduce lighting load ≥ 15 % for a control • Reduce lighting level to the uniform level of illumination requirement in Table 130.1-A from 2013 Title 24	• AutoDR-ready lighting control system OR • AutoDR-ready EMCS	1. Capable of receiving and automatically responding to at least one standards-based messaging protocol and enabling DR after receiving a DR signal. 2. Reduce lighting load ≥ 15 % using the illuminance measurement or full output test method.
Electronic Messaging Center (EMC)	• Lighting load > 15 kW	• Reduce power ≥ 30 %	• Centralized or decentralized AutoDR-ready lighting control system OR • AutoDR-ready EMCS	No acceptance test required
HVAC System with DDC to the Zone Level	• Non-critical zones	• Capable to remotely reset the temperatures or to original operating levels. • Capable to remotely setup the operating cooling set points by 4 degrees or more to a signal from a centralized contact or software point within an EMCS • Cooling set points in critical spaces do not change	• Centralized HVAC Controller OR • AutoDR-ready EMCS	1. The EMCS interface enable activation of the central demand shed controls 2. Same as system response requirements
HVAC System without DDC	• Non-temperature sensitive processes		• Demand-responsive setback thermostat (also called OCST) AutoDR-ready EMCS	No acceptance test required

terface supported by the U.S. Smart Grid Interoperability Panel (SGIP) is OpenADR version 2.0. This standard is listed in the SGIP Catalog of Standards (CoS), representing its relevance for the "development and deployment of a robust, interoperable, and secure Smart Grid" (SGIP. No date). OpenADR 2.0 has built-in security features with interoperability testing and certification support from the OpenADR Alliance. The SGIP CoS also lists other standards, such as Smart Energy Profile (SEP) and MultiSpeak. Figure 4 depicts a certified OpenADR 2.0 client in demand responsive controls to enable capability for interoperable communications with DR signals. The interoperability is possible here because, California utilities' deploy a certified OpenADR 2.0 server and require that DR client(s) for demand responsive controls be OpenADR 2.0-certified. OpenADR-certified products are referenced in a recent study as "the best way to ensure that controls meet the messaging protocol requirement of Title 24" (Energy Design Resources 2014). Combined, California utilities represent over 250 MW of AutoDR in over 1,200 facilities using OpenADR (Ghatikar et al. 2014b).

The 2013 Title 24 requirements are a step in right direction to enable more energy-efficient and grid-ready buildings and controls. To enable interoperable systems and scale deployments, the key terms and accepting testing for AutoDR must be well described. Examples of messaging standards and illustrations that show the architectures and the AutoDR requirements in the code can assist code diffusion by providing implementation scenarios.

Analysis and suggested recommendations for code diffusion

This section provides specific technical and programmatic recommendations to improve the code language and its potential for diffusion. These recommendations were based on background research, workshops, and surveys.

WORKSHOP AND SURVEY SUMMARY RESULTS

Lawrence Berkeley National Laboratory (LBNL) held a workshop for invited key stakeholders in DR and automation to review the code language in Title 24 concerning DR automation.

Contents Keywords Authors

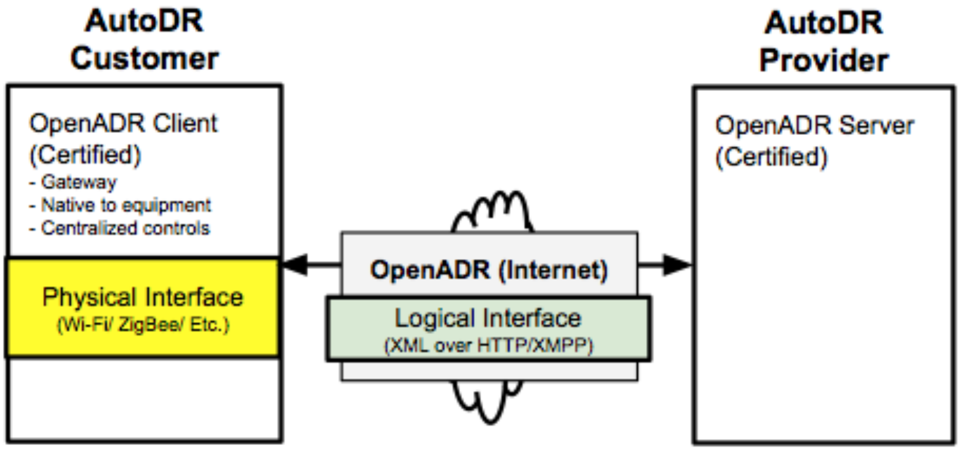

Figure 4. Interoperable communications of the logical interface using the OpenADR 2.0 standard.

The stakeholders consist of program managers, researchers, city officials, consultants, engineers from utility companies, nonprofit organizations, city building departments. The stakeholder workshop presented an opportunity to acknowledge emerging challenges and to gather data for practical recommendations for the adoption of DR automation. A survey was conducted after the workshop to prioritize tasks and activities, to improve the likelihood of achieving DR automation goals. Five questionnaires explored key issues in code language, compliance, market, and diffusion of DR automation. Fifteen of the 18 participants completed the survey.

The following recommendations provide guidance to meet the code requirements and promote the value of AutoDR-ready equipment and systems. They are based on survey results and workshop discussions.

a. AutoDR standards and acceptance test requirements should be clear, consistent, and easily understood

Lack of specifics and consistency in the code language is the core of the problem that can hinder code diffusion and adoption of DR automation. To provide clear guidance to a novice (who may even be new to the concept of DR automation), further improvements need to be made to the AutoDR-related standards and acceptance testing requirements in 2013 Title 24.

Results from two survey questionnaires identifying code language issues (Figure 5) show that the better understanding of the requirements for code compliance and clarity in standards-based messaging protocol requirements are the most important. In terms of lack of clarity of AutoDR standards and acceptance testing, nearly half of the participants responded that requirements for lighting controls are mostly well understood.

b. Accessible and understandable education and training programs should be provided, as should intuitive tools for code-compliance checking

There is scarcity of experts in DR automation relative to demand, and easily accessible and understood education and training programs and intuitive tools are not extensively available. Such expertise, programs, and tools would help bridge the widening knowledge gaps between customers and the DR programs of the utilities and AutoDR-related requirements in Title 24. Based on the survey results (Figure 6), two-thirds of participants agreed that providing tools for building design and code-check is the most critical element. Education and training was the third most important initiative to encourage mass adoption of DR automation, followed by guidance and code language to provide more clarity. Survey results show that deployment channels with direct access to customers and most interaction to a wider audience, such as utilities and public commissions, should lead this initiative to address the key issue in lack of understandings in AutoDR standards and automation requirements.

c. Utilities, city departments, and public commissions should build internal infrastructure to communicate existing and new AutoDR-related information to customers and building communities in a clear and consistent manner, and exchange feedback to improve program design and code language

Survey results show that utilities are considered to be the most ideal deployment channels for the adoption of DR automation. Leading forces behind DR automation, such as utilities, city departments, and public commissions, should act as a communication medium to provide existing and new information to the public systematically, by building internal infrastructure with advanced platforms and employing staff with expertise in DR automation. The information provided by customers and staff can be shared as a feedback mechanism and used to improve AutoDR program design and code language.

Global diffusion of the automation using building codes

We also reviewed the applicability of these recommendations to the rest of the U.S. and European building codes. These recommendations can be relevant to other countries that have building energy efficiency codes and plan to enable demand to participate in grid transactions.

We focus on building energy codes enforced at the state and local levels in the U.S. and reference European activities. In the U.S., California has been leading the code diffusion in DR and automation, with its inclusion in the 2008 and 2013 Title 24. Supported by the California utilities' AutoDR programs, the code adoption of DR automation has gained traction in the United States. The impact of code diffusion is expected to

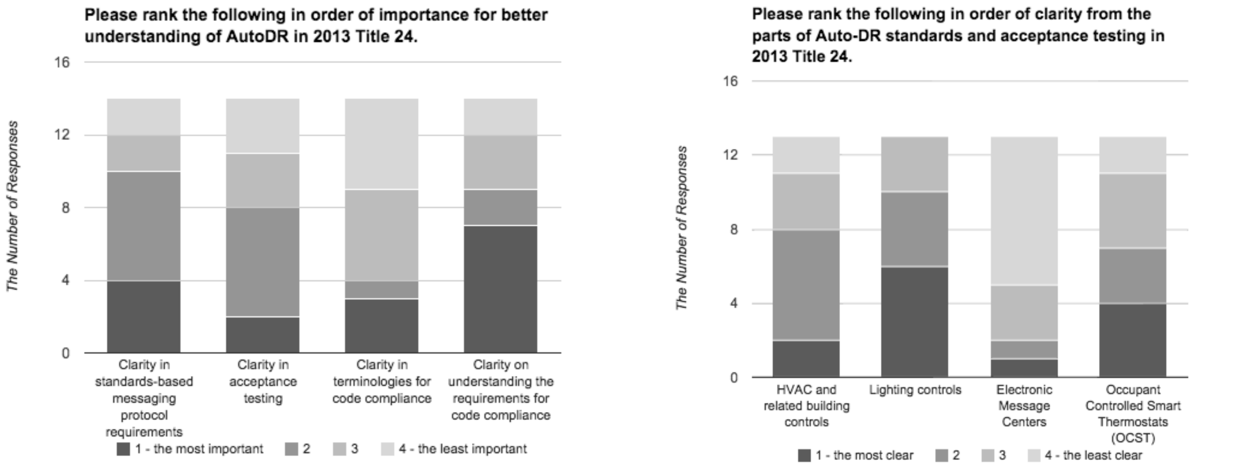

Figure 5. Survey results: AutoDR standards' clarity and acceptance testing priorities in 2013 Title 24. Figure 4. Interoperable communications of the logical interface using the OpenADR 2.0 standard.

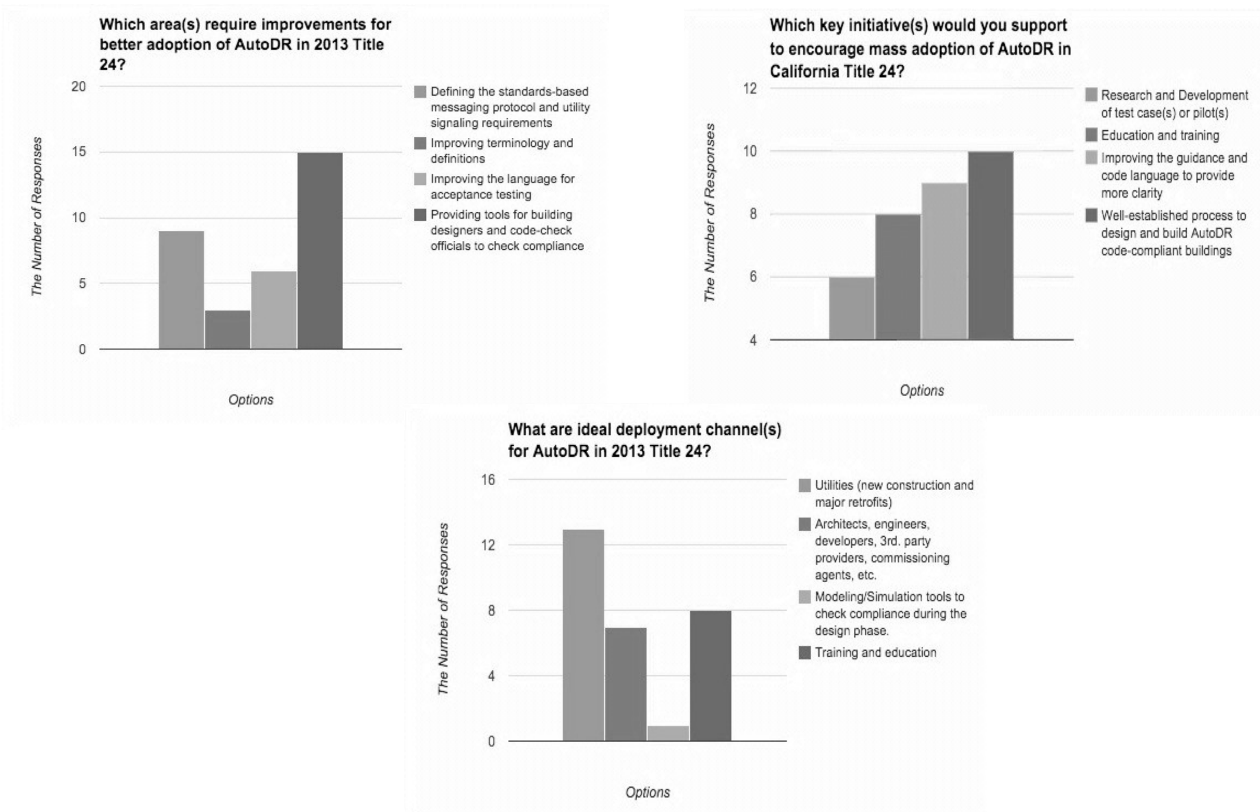

Figure 6. Survey results: Market adoption of DR automation.

be more significant in California, with the stringent requirements of DR automation in the 2013 Title 24. It is too early to determine the success of adopting the new AutoDR related requirements in California, as the 2013 Title 24 standards became effective only recently, on July 1, 2014. Figure 7 illustrates that 46 U.S. states have adopted voluntary energy codes, many of which are based on the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) 90.1, the International Residential Code (IRC), or the International Energy Conservation Code (IECC). Of these, 14 states have adopted ASHRAE 90.1-equivalent or more energy-efficient requirements as of December 2014 (Gonzales et al. 2014; DOE 2014).

There is a mix of voluntary and mandatory energy code and rating systems in the U.S. that have adopted DR or DR automation. The U.S. Green Building Council (USGBC) recently made a change to add a pilot credit 8: Demand Response in LEED v4 rating system with the requirement of AutoDR-ready systems. This move signifies the adoption status of DR automation in the United States. In Europe, DR automation in building codes is still a novel idea, and adoption is being discussed. For energy efficiency, there was a mandatory directive, Energy Performance of Buildings Directive (EPBD), which requires all European Union (EU) countries to improve their building regulations and to introduce building energy certification programs.

Additionally, the Energy Efficiency Directive (2012/27/EU) by the European Commission (EC) instituted in 2012 exemplifies a strong commitment to, and interest in, encouraging participation of member states in DR and potentially DR automation as their next step. The directive requires transmission system operators and distribution system operators of the member states to meet the requirements for balancing and ancillary services via DR providers. The mandatory requirements initiated from member states should increase the adoption rate of DR automation significantly. With increasing intermittent renewable energy resources and high electricity consumption in Europe, DR automation can be integrated to forthcoming energy initiatives to meet the 20 percent target set by the EC to reduce energy consumption and greenhouse gas emissions and to increase energy efficiency by 2020. While the initial building codes in California have focused on non-residential facilities, Europe may prioritize the codes on facilities with greatest AutoDR potential. The mandatory codes for DR automation enforced at a national level in the U.S. and Europe will be effective to increase the adoption rate of AutoDR, which helps to meet the national clean-energy objectives by reducing the use of fossil fuels for peak operational requirements and increasing renewable energy generation and its grid integration.

Discussions

This section reviews lessons learned from the AutoDR language in Title 24, stakeholder workshops, and experiences of deployments in DR programs. For California, we identify two key programmatic areas for future research and diffusion of AutoDR, as well as benefits. The first topic also focuses on improving the language for code compliance requirements (varying the degree of details for each end use), provision of technology and tools for code compliance, and DR program-based cost-effective methods for automation.

Area 1. Utilities and savings by design for energy efficiency

The following California utilities implement the Savings By Design (SBD) program on behalf of the California utility ratepayers to advance commercial building energy efficiency through Title 24 building code: Pacific Gas and Electric Company, Southern California Edison, San Diego Gas & Electric, Southern California Gas Company, Sacramento Municipal Utility District, and the Los Angeles Department of Water and Power. These utility companies could leverage the SBD program to include AutoDR diffusion strategies. Such a program would advance the development of guidelines for AutoDR standards and acceptance testing for new construction, and accelerate the automation uptake to support grid responsiveness in buildings through 2013 Title 24. The SBD for AutoDR must consider the following:

- **Code Compliance Requirements:** Use a clear and consistent language and process for AutoDR requirements, so they can be easily understood and adopted by customers.
- **Technologies and Tools:** Obtain a list of existing and new vendors complying with the AutoDR requirements. Clarify the acceptable standards-based messaging protocols and DR signals for the AutoDR acceptance and program enrollment. Provide tools for customers to check code compliance.
- **Automated Demand Response Program Design:** Report and share customers' feedback with other utilities and public commissions to improve program design and the code languages of AutoDR requirements in California Title 24.

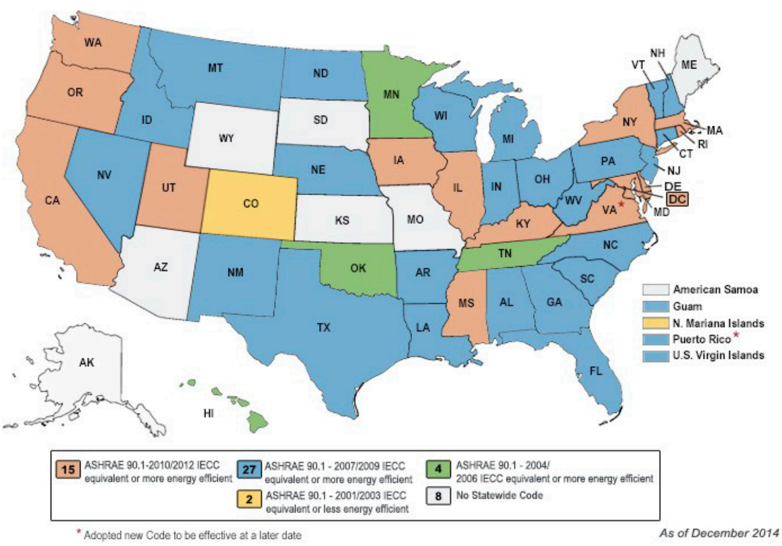

Figure 7. Adoption of commercial building energy codes in the United States (DOE 2014).

- **Cost Effectiveness of DR Automation:** The current costs to enable DR automation range from €160/kW to €280/kW (or $170/kW to $300/kW) (Ghatikar et al. 2014b). To reduce this cost further, we need to identify cost-effective methods for automation to encourage customer participation.

Area 2. Training for building owners, code officials, and customers

It is well known that successful implementation of Title 24 requires significant training. Key stakeholders to be informed, trained, and motivated include building permitting officials, building owners, engineering firms, architects, and contractors. It is useful to consider the results of recent research on the enforcement of acceptance tests that were required in the 2008 Title 24 code (Tyler et al. 2011). To determine the effectiveness of the acceptance test procedures, eight contractors were enlisted to perform multiple acceptance tests at 13 commercial buildings. The researchers observed and recorded the actual procedures used in the resulting 48 acceptance tests, and then compared the procedures with the Title 24 procedures that were required. The study showed that most contractors are somewhat familiar with the tests, but their perceived level of understanding exceeded their ability to perform the specified tests. Overall, this research illustrated that the success of the Title 24 acceptance test requirements depends on a chain of responsibility linking design engineers, contractors, sub-contractors, owners, and building officials. The same is likely to be true for AutoDR concepts in Title 24.

While there are efforts to provide guidelines to Title 24 stakeholders on the inclusion of AutoDR in the non- residential sector (Energy Design Resources 2014), our workshop survey recommended having knowledgeable staff to respond to customers' questions on AutoDR requirements, especially during the customer enrollment and qualification process. The stakeholders recommend training the code implementers and customers with existing and new information on AutoDR requirements in Title 24 and the acceptance testing.

BENEFITS TO CALIFORNIA FROM TITLE 24 BUILDING CODES

The 2013 Title 24 HVAC and lighting AutoDR guidance and requirements provide the groundwork for greater automated demand response potential in California, directly benefiting California's ratepayers and utilities. We see the following key benefits to California from this study, which can also be relevant to other jurisdictions:

- AutoDR guidelines and requirements will help the utilities and state regulatory agencies determine and develop tools that allow 2013 Title 24 to be effective in new construction and retrofits.
- Expanding on the obvious benefits of energy efficiency in building codes, the study findings will provide a basis for greater AutoDR access and diffusion within California's buildings.
- Clarity in AutoDR guidance language and accepting testing for compliance will facilitate better understanding of AutoDR requirements, which will encourage interoperable technology developments and enable buildings to be capable of providing grid services.
- Identification of cost-effective methods for DR automation and customer participation in DR programs.

Conclusions and future research directions

In this paper, we reviewed the California Title 24 building codes, including the key benefits they can offer for significant improvements in energy efficiency and the diffusion of DR and automation. We offered specific recommendations for DR automation to enable interoperability, eliminate technology obsolescence, and improve the cost-effectiveness of AutoDR and DR programs. Based on the research, stakeholder recommendations, and survey results, we recommended revisions to the code language and strategies for code diffusion.

These recommendations include both technical and programmatic activities. Two key technical challenges need to be resolved: (1) technology and equipment vendors must be able to ensure AutoDR compliance during product development, and ensure that when the equipment is installed in a building it is capable of demand-responsive control, and (2) customer participation (when chosen) must be made simple by plug-and-play features. The use of national and industry-supported open standards and third-party certification will play key roles in interoperability and cost effectiveness of the automation, especially at the logical interface levels where most innovation happens. Here, we suggest more specific direction for standards-based messaging protocol. The standards-based messaging protocol must conform to two-way communication that is defined in the U.S. Smart Grid Interoperability Panel (SGIP) Catalog of Standards (CoS) with a testing and certification program and a supporting authority. This requirement must be mandatory for all demand responsive controls that require AutoDR compliance.

Some examples of DR standards that support Title 24 over various *physical interfaces* include OpenADR and SEP. In the Title 24 and programmatic context, we have the following recommendations:

- Improve the acceptance tests language and process.
- Offer education and training programs with intuitive tools for code compliance.
- Utilities, state, and regional bodies must play a key role to build the infrastructure and communicate the intent of the code and AutoDR diffusion through an exchange of feedback with the implementers.

Title 24 codes must guide stakeholders such as electric utilities, building owners, code officials, and technology vendors, and must better define AutoDR and standards-based messaging protocol compliance requirements. These stakeholders must be educated on the intent of this new requirement, and electric utilities must be engaged to take advantage of the capability in new buildings. Such an engagement will enable better understanding of AutoDR guidelines in the Title 24 code and allow accelerated diffusion in California buildings, and thus provide cost-effective solutions for energy efficiency and DR integration. Since energy efficiency and DR are integral needs in the United States and other parts of the world, such as Europe, our recommendations have potential for global applications to advance sustainable and economically sound energy technologies and policies.

FUTURE RESEARCH DIRECTIONS

California's 2013 Title 24 building codes provide a big leap toward specifying the mandatory energy efficiency and AutoDR requirements in both residential and non-residential facilities; their accelerated adoption and impacts will be based on how the new codes will be adopted. For California, we recommend the following key AutoADR-focused research directions:

Valuing AutoDR for California

Three key barriers in the adoption of AutoDR are lack of understanding of: (1) the reliability of customer responses, (2) the cost-effectiveness it offers over traditional DR, and (3) new market opportunities for DR automation. These barriers could be addressed through the following key activities:

1. To improve the reliability of customers' responses from DR automation, the California utilities and regulatory agencies should understand customers' needs and the benefits of DR automation, and educate them on effective strategies that meet their system capabilities and needs.
2. For cost effectiveness, the vision for the future of AutoDR to lower the system-wide technology costs must be studied. Such a vision must consider the use of code-enabled demand responsive controls in multiple DR programs. Research and deployments should advance the vision where buildings interact with the grid at different time scales (e.g., day-ahead and day-of DR signals) where the code-enabled AutoDR technologies provide multiple value streams to the electric grid – at peak, or any time.
3. For new market opportunities for DR automation, standards-based AutoDR technologies must be evaluated for technical capability, to provide fast DR resources (e.g., day-of wholesale DR market signals), and lower cost by enabling native controls and interoperability. Such technologies also have the potential to enable better renewable integration through the participation of demand-side resources.

Accelerating technology diffusion and customer engagement

California utilities have played a key role in lowering energy use and facilitating the adoption of pre-2013 Title 24 building codes. The SBD program is an example of design assistance and financial incentives offered to building designers and owners. The same structure and market mechanisms could be leveraged to support AutoDR technology diffusion. In particular, utilities can plan a key role in supporting customer enrollment and participation in AutoDR programs by research and development of test cases and pilot programs and new construction. The findings from these pilots will better describe the guidelines for AutoDR capabilities, and standards-based messaging protocols will enable the development of interoperable controls and equipment that can respond to external DR signals. This can eventually lead to supporting the Title 24 objective: demand-responsive controls and low-cost automation through diffusion.

Glossary

ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
AutoDR	Automated Demand Response
CEC	California Energy Commission
CoS	Catalog of Standards
DDC	Direct Digital Controls
DOE	U.S. Department of Energy
DR	Demand Response
EMC	Electronic Message Center
EC	European Commission
EE	Energy Efficiency
EMCS	Energy Management Control System
EPBD	Energy Performance of Buildings Directive
EU	European Union
GWh	Gigawatt-hour
HERS	Home Energy Rating Systems
HVAC	Heating, Ventilation, and Air Conditioning
IEA	International Energy Agency
IECC	International Energy Conservation Code
IGCC	International Green Construction Code
IP	Internet Protocol
IRC	International Residential Code
ISO	Independent System Operator
LEED	Leadership in Energy & Environmental Design
MW	Megawatt
OCST	Occupant-Controlled Smart Thermostats
OpenADR	Open Automated Demand Response
OSI	Open Systems Interconnection
SBD	Savings By Design
SEP	Smart Energy Profile
SGIP	Smart Grid Interoperability Panel
TCP/IP	Transmission Control Protocol/Internet Protocol
UDP/IP	User Datagram Protocol/ Internet Protocol
USGBC	U.S. Green Building Council
XML	Extensible Markup Language

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